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Fertigation for efficient water and nutrient management in high density cashew plantation

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Abstract

An experiment was conducted to study the efficacy of fertigation for increasing the productivity of cashew under high density planting system (625 plants/ha). The optimal rate of fertilizer application was found as 125 g N, 31.25 g P_2O_5 and 31.25 g K_2O/tree/year through fertigation and 2 kg castor cake/tree through soil application (M3). The highest mean cashew nut yield of 2 t/ha/year and 1.96 t/ha/year was in treatments with 50% of recommended doses of fertilizers (RDF) through fertigation and 4 kg castor cake/tree through soil application (M6) and the treatment with half the aforesaid dose (M3). The protein content was high in fertigation treatment with 50 % RDF and 4 kg neem cake/tree(M5) (42.6 %), followed by M6 and M3 (40.7 and 40.2 %,respectively). In soil application with drip irrigation separately, the nut yield ranged from 1.45 to 1.73 t/ha/year and protein content from 35.9 to 38.9 %, respectively. The lowest nut yield of 1.12 t/ha/year was in absolute control and the lowest protein content of 35.9 and 36.2 % were in M9 and absolute control, respectively. Fertigation increased the nut weight to 7.0 g, apple weight to 76.9 g and the shelling percentage to 30.06 compared to soil application with a nut weight of 6.8 g, apple weight of 70.8 g and a shelling percentage of 29.5 and absolute control with a nut weight of 6.7 g, apple weight of 69.4 g and a shelling percentage of 28.8, respectively. The highest net profits of Rs. 49,367/ha/year and Rs. 47,393/ha/year were also from fertigation plots M4 (RDF through fertigation) and M3. The net profit from absolute control (M13) was Rs.32,425/ha/year. In soil application treatments with drip irrigation separately (M7 to M12), the net profit ranged from Rs.32,235 to Rs.40,417/ha/year. Soil and water conservation measures with mulching conserved soil moisture and reduced the optimal irrigation requirement to 20% Cumulative Pan Evaporation (CPE). Hence, increased irrigation rates (40 and 60 % CPE) did not have any significant effect on growth of cashew plants, nut weight, shelling percentage, yield etc. The levels of minor and micronutrients of the soil and defatted cashew kernel flour in fertigation treatments were on par with soil application with separate drip irrigation and were high compared to absolute control (except Zn). Different irrigation rates did not have significant effect on kernel N, P, K, Ca and Mg content but increased irrigation (20 to 40% CPE) increased the concentration of most of the major and micro nutrients present in leaf.

Keywords: Cashew, fertigation, high density planting system

Introduction

In the West Coast region of India, cashew, the perennial horticultural crop is mainly grown as a rainfed crop along the steep slopes of barren hillocks where the fertile topsoil is eroded and the murrum substratum is exposed. Here, the mean annual rainfall ranges from 3000 to 3500 mm and 80% of its contribution is during monsoon season (June to October). With the high intensity rainfall distributed over a short duration, the runoff and soil erosion are quite high in such steep slopes. In addition to these, due to the non-uniform distribution of rainfall, cashew experiences severe moisture stress from December to May, which adversely affects its flowering and fruit set causing flower drying and immature nut drop. The water deficit in cashew is high during March to May (Table 1). Even though cashew is a hardy crop, it responds well to water and manure (Richards, 1993; Yadukumar and Mandal, 1994; Latha *et al.,* 1996b and Yadukumar and Rejani, 2004). Cashew yield can be increased by 50 to 100 % through irrigation (Yadukumar and Mandal, 1994; Anonymous**,** 1998). The productivity of cashew can be significantly increased by the application of fertilizers/manures and also by adopting high-density planting system (Yadukumar *et al.,* 2003). In normal density planting system of cashew, the number of plants per hectare is 200, whereas in high density planting system it is 625. Richards (1993) studied the response of cashew to water using sprinkler irrigation and nutrients application in the sandy red soil of the Northern Territory, Australia. Kumar *et al*. (1998) from

Table 1. Water deficit and rainfall in mm (average of 10 years) during fruiting season of cashew (February to May)

Representative cashew growing areas	Water deficit during fruiting season (mm)				Average rainfall (mm) during fruiting season (Feb-May)
West Coast	Feb.	Mar.	Apr.	May	West Coast
Vengurla-Maharashtra	86	132	143	117	67 (2.3 %)
Puttur-Karnataka	90	142	112	140	237 (7.1 %)
Madakkathara-Kerala	110	126	59	183	415 (11.7%)
East Coast					
Vridhachalam-Tamilnadu	96	139	90	124	41 (3.4 %)
Bapatla-Andra Pradesh	114	90	124	83	284 (17.5%)
Bhubaneswar-Orissa	101	153	155	63	93 (8.0 %)
Jhargram-West Bengal	54	150	155	63	243 (15.0%)

Figures in parenthesis indicate % of the mean annual rainfall received.
Source: All India Coordinated Research Project on Cashew, Research Centres.

Agricultural Research Station, Ullal, Karnataka, India and found the superiority of fertigation in increasing the production of scion branches suitable for grafting. In India, though studies on irrigation and fertilizer application were done, so far no study was conducted on fertigation to improve fertilizer use efficiency and to achieve optimal irrigation in cashew planted under high density planting system. Therefore, the present study was taken up with the following objectives:

(i) to determine the optimum quantity of water and fertilizer to be applied through drip irrigation system (fertigation) for maximizing the yield of cashew in high density planting system.

(ii) for assessing the effect of fertigation and combination of fertilizers and organic manuring on the prominent variety of cashew, Bhaskara under high density planting system.

(iii) and to assess the quality of nuts produced in terms of protein, sugars and fat in kernels.

Materials and Methods

Study area

The experiments were conducted during 2001-2004 at National Research Centre for Cashew Experimental Station, Shantigodu (Latitude: 12.25° N, Longitude: 75.4° East), Puttur in Dakshina Kannada District of Karnataka, situated at 90 m above mean sea level. The study area is lying along the West Coast region of India and the climate is seasonally wet, dry tropics (hot humid) with distinct dry seasons (from January to April-May) during which the fruit development in cashew takes place. The average annual rainfall is 3500 mm and is distributed from late May to November. The soil is laterite gravelly with very low water holding capacity (12 to 22 % dry basis) and stores large amounts of water due to their deeper depth. Texturally, the soil of the experimental field is sandy clay loam. The soil is acidic with a pH value of .5.25 medium in N and low in P_2O_5 and K_2O contents.

Experimental details

Four years old cashew plants of Bhaskara variety planted at 4m x 4m spacing (625 trees/ha) was used as the high density planting system. The experiment was laid out by adopting split plot design with 12 main plots (manurial doses) (M-1 to M-12), three sub plots with irrigation (I-1 to I-3) and an absolute control plot (M-13) with three replications. The recommended dose of fertilizer (RDF) in fairly good soil with normal density planting system of cashew is 500 g N, 125 g P_2O_5 and 125 g K_2O/plant. The details of the treatments adopted in this experiment are as follows:

M-1 : 250 g N, 62.5 g P_2O_5, 62.5 g K_2O/plant (50% RDF) applied through drip irrigation (fertigation).

M-2 : 125 g N, 31.25 g P_2O_5, 31.25 g K_2O/ plant (25% RDF) applied through fertigation and 2 kg neem cake/plant through soil application.

M-3 : 125 g N, 31.25 g P_2O_5, 31.25 g K_2O/ plant (25% RDF) applied through fertigation and 2 kg castor cake /plant through soil application.

M-4 : 500 g N, 125 g P_2O_5, 125 g K_2O/plant (RDF) applied through fertigation.

M-5 : 50% RDF applied through fertigation and 4 kg neem cake /plant through soil application.

M-6 : 50% RDF through fertigation and 4 kg castor cake/plant through soil application.

M-7 : 50% RDF applied through soil application and drip irrigation separately.

M-8 : RDF applied through soil application and drip irrigation separately.

M-9 & M-10 : 25% RDF as inorganic and 2 kg organic manure (Neem and Castor cake) through soil application and drip irrigation separately.

M-11 & M-12 : 50% RDF as inorganic and 4 kg organic manure (Neem and Castor cake) through soil application and drip irrigation separately.

M13 : No irrigation and no manure-absolute control.

Sub plots : Three

I-1 : Drip irrigation-20% of CPE (Cumulative Pan Evaporation)

I-2 : Drip irrigation-40% of CPE

I-3 : Drip irrigation-60% of CPE

The first six main plot treatments (M1 to M6) were fertigation treatments and the fertilizers were applied in the form of Urea, Diammonium Phosphate and Potassium chloride (muriate of potash) in split doses from October to December in each month and fertigation was given once in a week from January to March by splitting the monthly dosage. Out of these six fertigation treatments, except treatment M1 and M4, organic manures like castor or neem cake was applied to soil. Initially a circular trench of size 25 cm width and 15 cm depth was dug out at 1.5 m away from the base of the tree and this trench was filled with cashew leaf litter collected from the base of the tree and over which the above-mentioned castor or neem cakes were spread uniformly and finally covered with thin layer of soil during August. This process enhances recycling of cashew leaf litter (approximately 8 kg/tree/year). In subsequent six treatments (M7 to M12), fertilizers were applied to soil in similar circular trenches during August and covered with leaf litter of cashew collected from the base of the plant and over which organic manures were applied as per the treatment requirements and finally thin layer of soil was applied to cover the manure and leaves. Absolute control treatment (M-13) was maintained without irrigation and fertilizer application. The fertilizer dosage fixed was 2/3rd in fourth year after planting and full dose from fifth year onwards. The NPK content (%) of the castor cake used was 5.8 - 6.4: 1.21: 1.25. Similarly, the NPK content of neem cake used was 5.7- 6.2: 1.2: 1.4, respectively. The castor and neem cake used were of first grade procured directly from processors. Lime was applied @ 0.5 kg/tree to the base of the plant at one-meter radius and forked into the soil during May-June, soon after the receipt of pre monsoon showers.

Irrigation requirement, growth and cashew nut yield

All the cashew plants were provided with soil conservation techniques like terracing and catch pit in addition to a thick mulch at the base of the plant to suppress weed growth, reduce soil temperature during peak summer season and reduce evaporation. In cashew, under high density planting system (4 m x 4 m), the effective roots are located within 1.5 m radius around the plant. Hence, the quantity of irrigation water was calculated based on the effective canopy spread of 7 m^2. Therefore, drip irrigation was given at the rate of 7 l/tree/day from December to January (Daily open pan water evaporation was 5 mm) and 9 l/tree/day from February to March (Daily open pan water evaporation was 6.5 mm) to meet 20 % of the Cumulative Pan Evaporation (CPE). Similarly, for 40 % and 60 % CPE, the irrigation rates were 14 l/tree/day and 21 l/tree/day from December to January and 18 l/tree/day and 27 l/tree/day from February to March, respectively. In order to meet 20 % CPE, two drippers of 2 l/h discharge rate were fitted at two equidistant points 1m away from the base of the tree. Similarly, to meet 40 and 60 % CPE, two drippers and three drippers of 4 l/h discharge rate were fixed. Drip irrigation was given for 1 h 45 min. during December and January and 2 h 15 min. during February and March. The data on growth and yield of cashew plants were collected for 2001-2004 and economics worked out. The average picking charges for nuts was Rs. 1.5/kg. The shelling percentage, kernel yield, nutrient content of soil, leaf and kernels were also determined as per standard procedures.

Major and minor nutrients of soil, leaf and cashew kernel

Soils at three depths (up to 90 cm) were collected and analysed. Fourth or index leaves at the time of flushing and cashew kernels were oven dried at 70° C and powdered. N was determined using Kjeltek Auto-Analyzer, P calorimetrically by Vanado Molybdo Phosphate method (Jackson, 1958), K was estimated using flame photometer and Ca, Mg, Fe, Zn, Mn and Cu were determined using Atomic Absorption Spectrophotometer (AAS) (by wet digest method).

Biochemical analysis

Nuts were shelled and kernels were extracted after the removal of testa with a mixture of chloroform and methanol (2:4 v/v) and the defatted cashew kernel flour was used for the estimation of total protein (N x 6.25) using Kjeltek 1030 Auto-analyser. Defatted cashew kernel flour was extracted with hot 80% ethanol and the ethanolic extract, after concentration, was fractionated into sugars. Sugars in the neutral fraction were estimated by phenol sulphuric acid method (Dubois *et al*., 1951). Residue after ethanol extraction was further extracted

with 52 % perchloric acid and starch was estimated (Clegg, 1956).

Statistical analysis

Data collected were statistically analysed using AGRISTAT package. The procedures used were Randomised Complete Block Design (RBD) for factor A with factor B, a split plot on A and two factor complete block design with split plot combined over the syears. For comparison of different treatments with absolute control (T13) only main plot data was considered and design used was RBD.

Results and Discussion

Effect of irrigation and manure on growth

Among the different irrigation rates, irrigation @ 20 % CPE was found to be optimal for high-density cashew orchards with soil and water conservation structures and mulching. The soil and water conservation measures and mulching helped to conserve more moisture in soil and hence the irrigation requirement was reduced to 20 % of CPE. Hence, higher irrigation rates and different fertigation and soil application treatments did not change the growth significantly in terms of stem girth, height, and canopy spread. Compared to the absolute control without irrigation and fertigation, increased growth was found in plots with manure application. Significant interaction effect between manure application and irrigation rates was not found. Similar studies conducted by Richards (1993) found that the canopy area and stem girth was more for treatments receiving irrigation and fertilizer application and the least for trees did not receiving either irrigation or fertilizers. He found that water rate had limited impact on canopy size, within treatment groups.

Effect of optimal irrigation and manure on yield and nut characteristics

The highest mean cashew nut yield (5th to 7th year after planting) of 2 t/ha/year was found when trees were subjected to fertigation with 50 % RDF and 4 kg castor cake/tree through soil application (M6), which was on par with the treatment of 25 % RDF through fertigation and 2 kg castor cake/tree through soil application (M3) (1.96 t/ha). This cashew nut yield trend shows that the treatment with 25 % of the RDF (50% lower dose of fertilizer) + 2 kg castor cake/tree along with the recyclable biomass available in the high density planting system was enough to meet the nutrient requirement of cashew. Hence, for optimum yield and for sustainable soil management, the treatment with reduced manure dose i.e.25 % of the RDF through fertigation + 2 kg castor cake/tree through soil application has to be preferred. These aforesaid treatments were also on par with M4 and M5 and were significantly superior to M1, M2 and M7 to M12 treatments. In soil application with drip irrigation separately, the nut yield ranged from 1.45 to 1.73 t/ha/year and the lowest nut yield of 1.12t/ha/year was found in absolute control. Fertigation increased the nut weight to 7.0 g, apple weight to 76.9 g and the shelling percentage to 30.06 compared to soil application coupled with drip irrigation separately with a nut weight of 6.8 g, apple weight of 70.8 g and a shelling percentage of 29.5and absolute control with a nut weight of 6.7 g, apple weight of 69.4 g and a shelling percentage of 28.8,respectively. In general, fertigation treatments increased the mean cashew nut yield (1.83 t/ha) compared to soil application with drip irrigation separately (1.64 t/ha) and absolute control (1.1 t/ha) (Table 2). Mahanthesh and Melanta (1994) found the highest yield in cashew trees treated with the highest dose of NPK.

Table 2. Effect of fertigation on nut yield, nut weight, apple weight and shelling percent of Bhaskara variety (mean of three years)

Main effects	Nut yield (kg/tree)	Nut yield (t/ha)	Nut wt. (g)	Apple wt. (g)	Shelling (%)
M1	2.50	1.56	6.84	74.95	30.28
M2	2.60	1.63	6.99	75.55	29.95
M3	3.14	1.96	7.03	77.70	29.72
M4	3.13	1.95	7.20	78.65	29.93
M5	3.01	1.88	7.03	76.30	30.32
M6	3.20	2.00	7.10	78.25	30.86
Mean	2.93	1.83	7.03	76.90	30.06
M7	2.33	1.45	6.68	73.95	29.17
M8	2.74	1.71	7.04	71.20	29.14
M9	2.50	1.56	6.74	68.80	29.27
M10	2.72	1.70	6.84	70.30	29.35
M11	2.77	1.73	6.87	67.30	30.03
M12	2.72	1.70	6.72	73.15	29.75
Mean	2.63	1.64	6.82	70.78	29.45
G mean	2.67	1.67	6.92	73.84	29.75
M13	1.80	1.12	6.67	69.40	28.81
Sem+	0.16	1.00	0.107	1.762	0.415
CD(P=0.05)	0.32	2.00	0.222	3.637	NS
Sub effects					
S1	2.77	1.73	6.89	73.37	29.66
S2	2.80	1.75	6.98	75.00	29.74
S3	2.76	1.73	6.90	73.16	29.82
Mean	2.78	1.74	6.92	73.84	29.74
Sem+	0.050	0.312	0.056	0.756	0.120
CD (P=0.05)	NS	NS	NS	NS	0.242

NS = Not Significant

Different irrigation rates (I-1: 20 % CPE, I-2: 40 % CPE and I-3: 60 % CPE) did not significantly affect nut weight, apple weight and shelling percentage (Table 2). Kumar *et al.* (1993) studied the effect of NPK on growth and yield of cashew under rainfed conditions in Agricultural Research Station, Ullal, Karnataka and obtained an average yield of 6.2 kg to 7.8 kg/tree in 10-14 year old plants with different NPK levels as against 2.4 kg/tree without nutrition. The highest shelling percentage of 33.1 was in trees supplied with 500:250:250 g NPK/ tree. Kumar *et al.* (1995) found that the duration of harvesting has increased significantly due to increased levels of NPK, whereas, the season of harvesting was found to be much earlier. Similarly, nut yield, number of nuts per tree, shelling percentage and kernel weight were increased significantly due to increased levels of NPK.

In high density planting system with irrigation, during March, the mean soil moisture content at 0 to 125 cm depth from the plot with soil and water conservation and mulching after one day irrigation (in all the three irrigations) was found to be in saturation and ranged from 34 to 22% (dry basis). With only soil and water conservation and mulching, it was 12.5 to 16% and in absolute control it was 10 to 12% (dry basis). The available soil moisture ranges from 12 to 22 % (dry basis) (Yadukumar, 2005). Among the treatments of three different irrigation rates, no significant difference in yield was noticed. This shows that the soil and water conservations measures adopted and the mulching provided in the high density planting system of cashew helped to conserve soil moisture and reduce the optimal irrigation requirement to 20% of CPE. Hence, in high density cashew orchards (625 trees /ha) of 5 to 7 years old with soil and water conservation measures and mulching requires only 984 l of irrigation water per season (20 % of CPE) during December to March. It was found that in normal density planting system, irrigation required is 80 L/tree once in four days and total thirty irrigations (2400 l per season) are required (Anonymous, 1998).

Latha and Salam (2001) found that in rainfed trees, application of N 500 g/tree/year produced 0.77 kg nuts/ tree while trees applied with no N resulted in zero yield. In irrigated trees (40 l/tree/day), N application of 1.5 kg/ tree/year resulted an increase in yield by 54% compared to rainfed trees. When the irrigation level was increased to 80 l/ tree, the yield increased was 124%.

Economics

Economic analysis for 2001-2004 (mean of three years) indicated that the highest net profit of Rs. 49, 367/ ha/year and Rs. 47,393/ha/year were also from fertigation plots M4 (RDF through fertigation) and M3 (25% RDF through fertigation + 2 kg castor cake/tree through soil application), respectively. The net profit from absolute control (M13) was Rs.32, 425/ha/year (Table 3). In soil application treatments (M7 to M12) with drip irrigation separately, the net profit ranged from Rs.32, 235 to Rs.40, 417/ha/year. The highest net profit and yield were found in fertigation treatments compared to soil application with drip irrigation separately and absolute control (Fig. 1). The highest B:C ratio was obtained for the absolute control due to fact that the cost of cultivation was less in this case since no installation of drip irrigation system and irrigation costs are involved.

Table 3. Economics worked out main plot treatment wise for high density planting system with Bhaskara variety (Rs. /ha) Mean of three years

Particulars of field operations	Treatments												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Jungle clearance	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200
Cost of manure	3063	6538	6538	4363	13463	13463	2619	5239	6319	6319	13019	13019	0
Manure application	3125	3125	3125	3125	3125	3125	3125	3125	3125	3125	3125	3125	0
Drip irrigation*	1875	1875	1875	1875	1875	1875	1875	1875	1875	1875	1875	1875	0
Yearly irrigation	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	0
Pruning	938	938	938	938	938	938	938	938	938	938	938	938	938
Plant protection**	3125	3125	3125	3125	3125	3125	3125	3125	3125	3125	3125	3125	3125
Cost of picking nuts***	2340	2444	2942	2933	2825	3000	2180	2571	2339	2555	2595	2553	1688
Total cost of cultivation	17166	20745	21243	19059	28051	28226	16562	19573	20421	20637	27377	27335	6951
Yield (kg/ha)	1560	1629	1961	1955	1883	2000	1453	1714	1559	1703	1730	1702	1125
Cost of produce	54600	57015	68635	68425	65905	70000	50855	59990	54565	59605	60550	59570	39375
Profit	37434	36271	47393	49367	37855	41774	34294	40417	34145	38969	33173	32235	32425
B C Ratio	3.18	2.75	3.23	3.59	2.35	2.48	3.07	3.06	2.67	2.89	2.21	2.18	5.67

* Cost of drip irrigation unit distributed for 10 years with yearly depreciation value of 10 percent

** Plant protection measures for controlling Tea mosquito bug

*** Average cost of picking cashew nuts in high density cashew plantations is @Rs.1.5/kg.

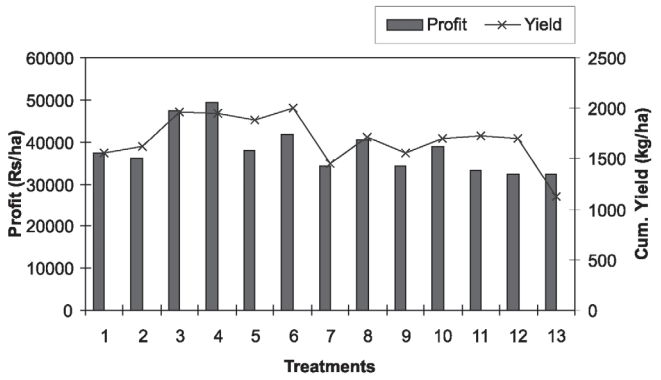

Fig. 1. Effect different fertigation treatments on nut yield and net profit

Effect of fertigation on major nutrient content of soil

The highest available N (315.1 kg /ha) was seen in the treatment M5 with 50 % of RDF through fertigation and 4 kg neem cake /tree through soil application (M5) and was significantly superior to rest of the treatments except M3, M4 and M6 (other fertigation treatments). The lowest available N (175.1 kg /ha) was in absolute control (M13). In general, fertigation treatments increased the available soil N compared to soil application with drip irrigation separately and absolute control (Fig. 2). Application of recommended and higher doses of inorganic fertilizers through fertigation or through soil did not change the P_2O_5 and K_2O contents of soil significantly. The lowest P_2O_5 of 15.6 kg/ha was in absolute control and the lowest K_2O content of 89.2 kg/ha was in M7 treatment. No significant difference in Ca and Mg content of soil was found among different treatments. In the multiple regression analysis of yield and N, P_2O_5 and K_2O of soil, the R^2 value obtained was 0.73 showing a positive relation of NPK with yield.

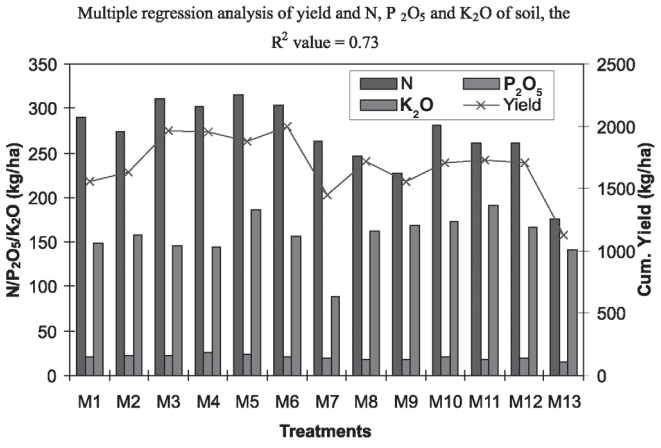

Fig. 2. Effect fertigation treatments on soil NPK and nut yield

Effect of fertigation treatments on soil micronutrient contents

The highest Zn (26.8 ppm) was found in M6 (Fig. 3) and the least (18.3 ppm) in absolute control. Fe content was high (84.7 ppm) in M6 treatment compared to the rest of the treatments including absolute control (50.7 ppm). Similarly, Mn was high in M3, M6 and M12 treatments. Cu content was higher in soil receiving treatment M6 (11.2 ppm) compared to the remaining treatments. The least Cu content was in soil receiving M2 treatment (7.4 ppm). In general, soil micronutrients in fertigation treatments were on par with soil application with drip irrigation separately and was high compared to absolute control. Treatments with castor cake (M6) has high Zn concentration and increased cashew yield.

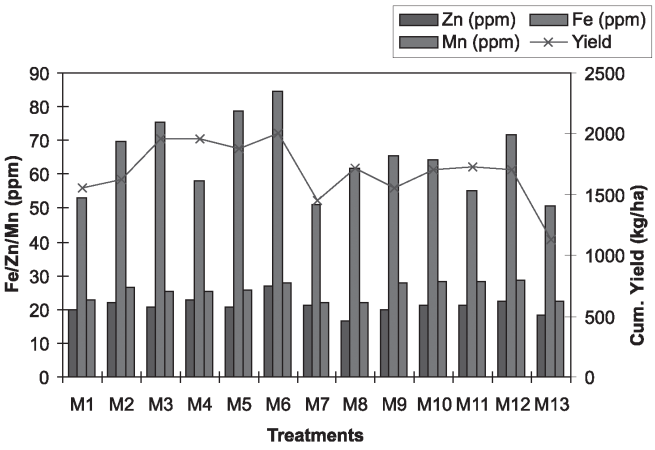

Fig. 3. Effect fertigation treatments on soil micronutrients and nut yield

Effect of fertigation on nutrient concentrations of leaves

The highest leaf N concentration (2.1 and 2.0 %) was in M5 and M6 and the lowest (1.6 %) in M12 and absolute control (Table 4). In different irrigation treatments ranging from 20 to 60 % CPE, N and P concentration in leaf increased upto 40 % CPE. The highest leaf P concentration (0.5 %) was in M1 and was significantly superior to rest of the treatments and the lowest (0.2 %) in absolute control. The highest leaf K concentration (0. 6 %) was in M3 with 25 % of RDF applied through fertigation and 2 kg castor cake/tree through soil application and the lowest (0.3 %) in absolute control. Different irrigation treatments (20 to 40 % CPE) increased K concentration (0.45 % to 0.52 %) in leaf. Harishu Kumar and Sreedharan (1987) determined the critical concentrations of N and P in cashew leaf with reference to yield as 2.09% and 0.14%. The highest leaf Zn concentration (16.4 ppm) was in M4 and the lowest (13.2 ppm) in M1 (Table 5). Different irrigation rates

Table 4. Effect of different treatments on leaf nutrient concentration in high density planting system (Bhaskara variety)

Treatments	N (%)	P (%)	K (%)	Fe (ppm)	Zn (ppm)	Mn (ppm)	Cu (ppm)
Main effects							
M1	1.90	0.51	0.42	28.19	13.27	9.85	7.93
M2	1.94	0.41	0.46	21.38	13.91	10.87	7.30
M3	1.95	0.39	0.57	22.79	15.55	10.27	5.95
M4	1.95	0.32	0.49	30.86	16.39	10.87	6.97
M5	2.08	0.38	0.52	24.44	15.82	10.3	5.07
M6	2.04	0.33	0.48	24.99	16.23	11.00	6.78
Mean	1.98	0.39	049	25.44	15.19	10.52	6.67
M7	1.97	0.31	0.45	21.18	15.12	10.32	4.93
M8	1.94	0.33	0.51	21.11	16.32	10.07	6.68
M9	2.01	0.32	0.49	23.58	15.87	11.23	5.10
M10	1.69	0.34	0.45	27.08	13.33	10.43	5.18
M11	1.75	0.34	0.50	22.91	14.19	12.62	5.78
M12	1.62	0.32	0.49	23.26	14.77	9.75	4.18
Mean	1.83	0.33	0.48	23.19	14.93	10.74	5.31
G mean	1.90	0.36	0.49	24.31	15.06	10.63	5.99
M13	1.63	0.18	0.33	20.86	15.03	7.80	4.28
Sem+	0.14	0.04	0.04	2.35	1.05	0.67	1.07
CD (P = 0.05)	0.28	0.09	009	4.83	NS	1.38	0.52

NS = Not Significant

showed no difference in leaf Zn concentration. The highest Mn contents of 12.6 and 11.2 ppm were found in the leaf of trees receiving M11 and M9 treatments and the lowest content of 7.8 ppm in absolute control. Leaf Mn increased up to 40% CPE irrigation. The highest iron concentration (30.9 ppm) was in M4 and the lowest (20.9 ppm) in absolute control. Increased quantities of irrigation increased leaf Fe and Cu concentration. The highest Cu concentration (7.9 ppm) was in M1 and the lowest (4.2 ppm) in M12 and absolute control (4.3 ppm). Kumar *et al.* (1998) found high yields in cultivars with higher absorption and utilization of NPK and their ability to counteract the adverse effects of Fe, Mn and Cu.

Influence of fertigation on nutrient concentrations and quality of cashew kernels

The highest kernel N concentration (6.8 and 6.5%) was in trees receiving M5 and M6 treatments and lower in M11 (5.7 %) and absolute control (5.4 %). Kernel P, K, Ca and Mg in fertigation treatments were on par with soil application treatments with drip irrigation separately (Table 5). The highest kernel Zn was in M12 (63.2 ppm) and the lowest in M6 (36.8 ppm). The kernel Fe was

Table 5. Effect of different treatments on nutrient content, protein, starch and sugar concentration in kernels (defatted flour) in high density planting system (Bhaskara variety)

Treatments	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Zn (ppm)	Fe (ppm)	Mn (ppm)	Cu (ppm)	Protein (mg/100 g)	Starch (mg/100 g)	Sugar (mg/100 g)
Main effects												
M1	6.17	0.28	0.34	0.05	0.26	53.06	69.69	24.06	26.07	38.60	42.87	5.76
M2	6.20	0.31	0.32	0.04	0.24	45.14	58.43	26.02	17.76	38.72	45.64	7.68
M3	6.43	0.49	0.32	0.03	0.21	43.32	66.87	21.09	21.37	40.19	47.25	6.19
M4	6.03	0.57	0.33	0.04	0.21	40.82	67.94	23.15	22.01	37.68	45.00	7.03
M5	6.81	0.49	0.32	0.04	0.19	39.28	51.71	18.34	19.36	42.58	40.62	6.15
M6	6.51	0.45	0.31	0.04	0.16	36.84	40.11	21.00	12.46	40.68	39.51	6.93
Mean	6.36	0.43	0.32	0.04	0.21	43.08	59.12	21.44	19.84	39.70	43.5	6.6
M7	6.00	0.45	0.33	0.05	0.19	42.44	74.47	20.27	16.54	37.49	38.12	7.5
M8	6.22	0.49	0.32	0.04	0.22	47.41	74.70	22.16	14.33	38.89	36.22	7.57
M9	5.75	0.57	0.32	0.04	0.23	52.32	49.61	15.58	23.87	35.92	34.31	7.47
M10	5.86	0.48	0.31	0.05	0.20	46.93	50.16	15.53	12.40	36.62	34.64	5.55
M11	5.69	0.49	0.31	0.05	0.20	51.13	46.49	15.09	11.60	36.55	33.01	5.55
M12	6.19	0.56	0.31	0.05	0.21	63.18	42.69	17.52	25.27	37.69	34.96	6.18
Mean	5.95	0.51	0.32	0.05	0.21	50.57	56.35	19.86	17.34	37.20	35.2	6.6
G mean	6.15	0.47	0.32	0.04	0.21	46.82	57.74	19.79	18.59	38.50	39.3	6.6
M13	5.42	0.44	0.29	0.03	0.19	59.68	39.94	16.43	21.51	36.17	33.7	6.14
CD (P = 0.05)	0.62	0.01	0.019	0.004	0.022	5.46	6.23	3.37	0.79	2.47	NS	0.41
Sub effects												
S1	6.16	0.47	0.32	0.04	0.22	46.87	5019	18.97	18.10	41.60	33.2	5.75
S2	6.16	0.46	0.32	0.04	0.21	45.47	5242	21.50	16.81	41.61	34.9	5.93
S3	6.14	0.48	0.32	0.05	0.23	48.14	53.40	21.48	20.02	41.37	36.2	6.69
Mean	6.15	0.47	0.32	0.04	0.21	46.82	52.33	20.65	18.30	41.53	34.7	6.12
CD (P = 0.05)	NS	NS	NS	0.009	NS	2.33	NS	1.31	0.79	NS	1.85	0.17

NS = Not Significant

high in M7 and M8 (74.7 and 74.5 ppm) and was low in absolute control (39.9 ppm). The highest kernel Mn (26.0 ppm) was in M2 and the highest Cu (26.1 ppm) was in M1 treatment and the lowest in M11 (Mn – 15.1 ppm and Cu – 11.6 ppm, respectively (Table 5). Increased irrigation rates did not increase the major, minor and micronutrient contents of the defatted kernel flour. Protein content of defatted kernel flour was significantly high (42.6 %) in M5, M6 (40.7%) and M3 (40.2%) treatments and was low (35.9 and 36.2 %) in M9 and absolute control (Table 6). In general, fertigation treatments improved the kernel N, Fe, Mn, Cu, protein and starch compared to soil application treatments with drip irrigation separately and the absolute control. Latha *et al.,* (1996a) found that NPK content increased the protein content of nuts while increased rate of P and K had no significant effect on protein content of nuts.

Conclusions

The highest mean cashew nut yield of 2 t/ha/year and 1.96 t/ha/year was in treatments with 50% RDF through fertigation and 4 kg castor cake/tree through soil application (M6) and the treatment with half the aforesaid dose (M3). The protein content was high in fertigation treatment with 50% RDF and 4 kg neem cake/tree (M5-42.6%) followed by M6 and M3 (40.7 and 40.2%). In soil application treatments with drip irrigation separately, the nut yield ranged from 1.45 to 1.73 t/ha/year and protein content ranged from 35.9 to 38.9 %, respectively. The lowest nut yield of 1.12 t/ha/year was in absolute control and the lowest protein content of 35.9 and 36.2% were in M9 treatment and absolute control, respectively. Fertigation increased the nut weight to 7.0 g, apple weight to 76.9 g and the shelling percentage to 30.06 compared to soil application coupled with drip irrigation separately with a nut weight of 6.8 g, apple weight of 70.8 g and a shelling percentage of 29.5 and absolute control with a nut weight of 6.7 g, apple weight of 69.4 g and a shelling percentage of 28.8, respectively. The highest net profit of Rs. 49,367/ha/year and Rs. 47,393/ha/year were also from fertigation treatments M4 (RDF through fertigation) and M3 (25 % RDF through fertigation + 2 kg castor cake/tree through soil application). The net profit from absolute control was Rs.32,425/ha/year. In soil application treatments with drip irrigation separately, the net profit ranged from Rs.32,235 to Rs.40,417/ha/year, respectively. Fertigation was found superior to soil application treatments with drip irrigation separately+ and absolute control in terms of nut yield, nut weight, apple weight, shelling percent and net profit. The optimal rate of fertilizer application was found as 125 g N, 31.25 g P_2O_5 and 31.25 g K_2O/tree/year through fertigation and castor cake 2 kg/tree through soil application (M3) which is on par with trees receiving 250 g N, 62.5 g P_2O_5 and 62.5 g K_2O/tree/year through fertigation (M6). In view of sustainable agriculture, it is better to adopt M3 where lower fertilizer dose was used. The optimal rate of drip irrigation was found as 20% CPE due to the conservation of soil moisture by soil and water conservation structures and mulching at the base of cashew plants. Increased irrigation rates (40 and 60 % CPE) did not have any significant effect on growth of cashew plants, nut weight, shelling percentage, yield etc. The levels of minor and micronutrients of soil and defatted cashew kernel flour in fertigation treatments were on par with soil application with irrigation treatments and were high compared to absolute control (except Zn). Different irrigation rates did not significantly affect on kernel N, P, K, Ca and Mg content but increased irrigation (20 to 40% CPE) enhanced the concentration of most of the major and micro nutrients present in leaf.

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